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Aster quanzhouensis (Asteraceae), a new riparian species from eastern China

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Abstract

Aster quanzhouensis **sp. nov.** (Asteraceae) from Fujian, eastern China, is described and illustrated. It grows on rocks in the riparian zone. Morphological, cytological and molecular investigations of *A. quanzhouensis* were carried out. The morphological data and phylogenetic analysis based on combined ITS, ETS and *trnL-F* dataset suggest that *A. quanzhouensis* is a separate species closely related to *A. tonglingensis*. The new species differs from the latter by the shorter stem length, leaf morphology, colour of phyllaries, number of ray florets, and achene shape. The cytological observation shows that the new species is diploid with a karyotype of 2n = 18.

Keywords

Asteraceae, *Aster quanzhouensis*, new species, taxonomy

Introduction

The genus *Aster* L. in its recent circumscription is restricted to Eurasia and comprises ~ 150 species, of which 123 occur in China (Chen et al. 2011), a main diversity centre of *Aster* (Li et al. 2012). Recently, ten new *Aster* species have been described, and almost all these species have a narrow distribution pattern known from only one or two populations in different regions of China (Zhang et al. 2015, 2019; Li et al. 2017, 2020; Xiao et al. 2019a, b, 2020, 2021; Xiong et al. 2019).

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Recently, Guo-Jiao Yan, a young amateur naturalist and one of the authors of this paper, collected some unique samples from the riversides of the Min and Jin rivers, Quanzhou city, Fujian, eastern China. The morphological, cytological and phylogenetic data show that the specimens represent an undescribed species, which is reported herein.

Materials and methods

Material collection

Specimens of the new taxon were collected in Dehua and Yongchun counties (Fig. 1), Fujian, China. We collected leaf material and dried it with silica gel for molecular experiments. The voucher specimens were deposited at the Herbarium of Hunan Normal University (HNNU) and Jiangxi Agricultural University (JXAU).

Morphological observations

The description of the new species is based on living material, dry specimens and FAA-fixed materials. Twenty-one individuals were examined. The morphological comparison with *Aster tonglingensis* G.J.Zhang & T.G.Gao is based on the study of herbarium specimens, from PE, HNNU and JAXU. We compared the shape and size of the leaves, length of stems, phyllaries, number of florets, and achenes.

Cytology

Excised root tips from the cultivated plants of the new species were pretreated with 0.1% colchicine at 10 °C for 4 h, then fixed in Carnoy's solution (95% ethanol and glacial acetic acid in 3:1 ratio) at 20 °C for 12 h. The root tips were then macerated in 1 M hydrochloric acid at 60 °C for 10 min, stained in Carbol fuchsin solution, washed in distilled water for 30 min and finally depigmented and squashed in 45% acetic acid (Li et al. 2011). Karyotype formulae were calculated based on measurements of mitotic metaphase chromosomes taken from photographs. The symbols used to describe the karyotypes followed Levan et al. (1964).

Taxon sampling, DNA extraction, PCR reaction and sequencing

Nuclear ribosomal DNA ITS and ETS sequences and plastid DNA *trnL-F* sequences of 66 species and varieties, representing major clades of the genus *Aster* and its relatives (Li et al. 2012, 2017, 2020; Zhang et al. 2015, 2019; Xiao et al. 2019a, b, 2020, 2021), were downloaded from GenBank (Appendix 1). Besides, eleven newly sequenced accessions are included from Dehua and Yongchun counties two individuals of *Aster quanzhouensis* (Appendix 1). The names of the taxa mentioned above follow Chen et al. (2011). *Grangea maderaspatana* (L.) Poir. and *Dichrocephala integrifolia* (L.f.) Kuntze were selected as outgroups following

Li et al. (2012). Voucher specimens of newly sequenced material were deposited in HNNU. Total DNA extraction, PCR and sequencing were carried out according to Li et al. (2012).

Phylogenetic analysis

Boundaries of the ITS, ETS and *trnL-F* regions were determined through comparison with previously published sequences (Li et al. 2012). DNA sequences were aligned initially using Clustal X1.83 (Jeanmougin et al. 1998), performed by MUSCLEv3.8.31 (Edgar 2004), and adjusted manually in PhyDE ver0.9971 (Müller et al. 2010). The optimal model of DNA substitutions was selected using the Akaike information criterion (Akaike 1973) as applied in jModelTest 2.1.4 (Darriba et al. 2012) prior to the maximum likelihood (ML) analyses and Bayesian inference (BI). The best fit models for ITS, ETS and *trnL-F* were GTR + G, GTR + I + G and TVM+I, respectively. Phylogenetic trees were constructed using maximum likelihood (ML) and Bayesian inference (BI). Maximum likelihood (ML) and Bayesian inference (BI) analyses were conducted using RAxML 7.2.6 and MrBayes 3.1.2 (Huelsenbeck and Ronquist 2001; Stamatakis 2006), respectively. For BI, four chains, each starting with a random tree, were run for 1,000,000 generations with trees sampled every 1000 generations. The average standard deviation of split frequencies (< 0.01) was used to assess the convergence of the two runs. After the first ca. 25% discarded as burn-in, the remaining trees were imported into PAUP* v.4.0b10 and a 50% majority-rule consensus tree was produced to obtain posterior probabilities (PP) of the clades. Before the datasets were combined, the incongruence length difference test (Farris et al. 1994) was performed on PAUP* v.4.0b10 (Swofford 2001).

Results

Aster quanzhouensis **M.Tang, G.J.Yan & W.P.Li, sp. nov.**
urn:lsid:ipni.org:names:77297480-1
Figs 1–3

Type. China, Fujian province, Quanzhou city, Dehua county, Nancheng town, alt. ca. 500 m, 25°34.20'N, 118°29.65'E, 5 Oct 2021, Guo-Jiao Yan, YGJ2110003 (Holotype: HNNU!, isotypes: HNNU!, JXAU!) (Fig. 3).

Additional collection seen. China. Fujian province, Quanzhou city, Yongchun county, alt. ca. 500 m, 25°24'N, 118°21'E, 30 Nov 2021, Guo-Jiao Yan, YGJ21113001 (HNNU!).

Diagnosis. *Aster quanzhouensis* differs from *A. tonglingensis* by its stems only 21–30 (60) cm (vs. 70–100 cm) long, narrowly lanceolate (vs. lanceolate) rosulate leaves, purplish-red (vs. green) apices of the phyllaries, 9–20 (40) (vs. more than 30) capitula, 7–11 (vs. ca. 15) ray florets, 11–14 × ca. 2 mm (vs. 7–10 × ca. 2 mm) lamina, two- or three-ribbed (vs. 4-ribbed) achenes and flowering period (Sep to early Dec vs. Jul) (Figs 2, 3, Table 1).

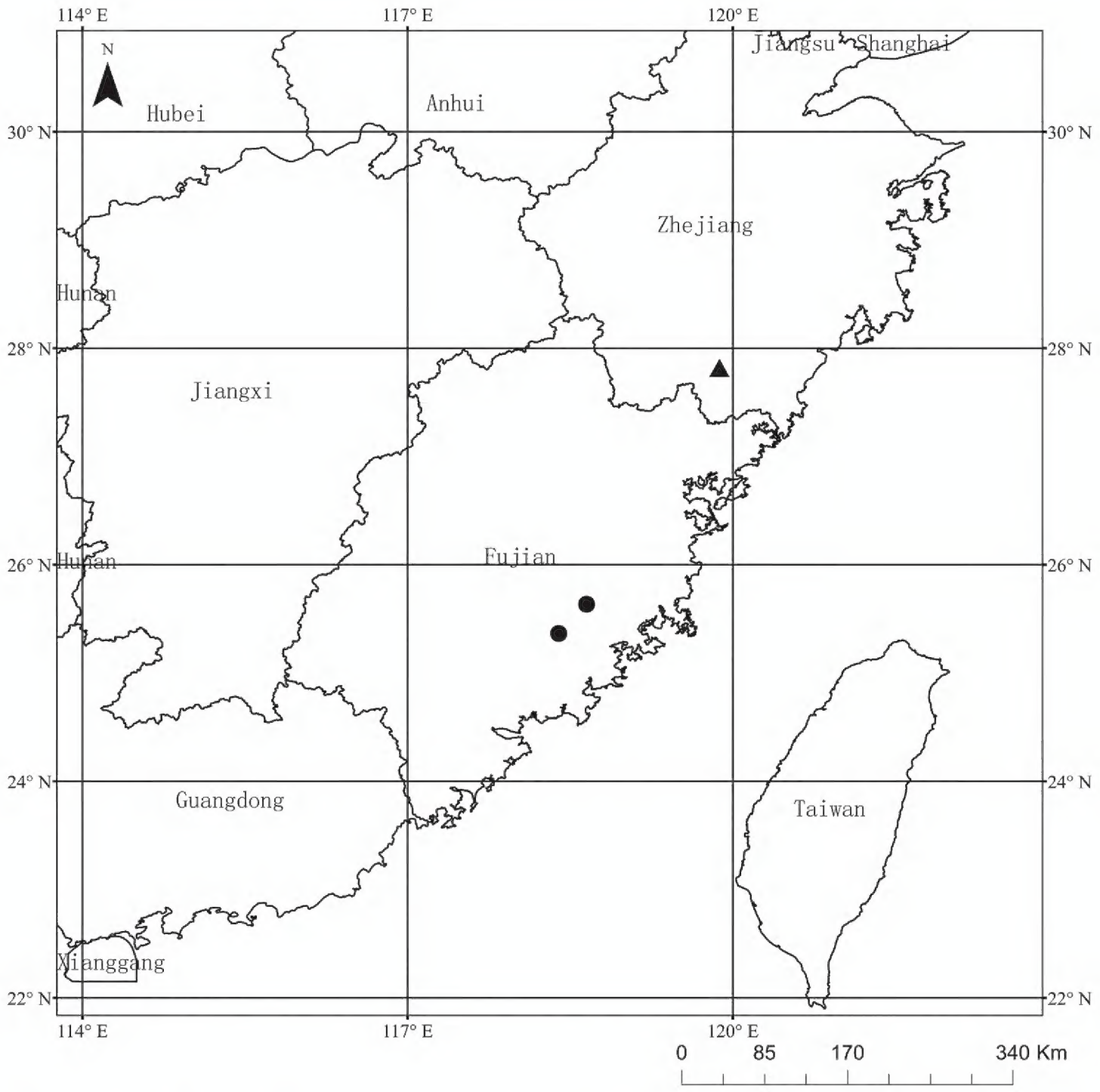

Figure 1. Distribution of *Aster quanzhouensis* (black circle) and *A. tonglingensis* (black triangle).

Description. Perennial herb, 21–30 (60) cm high. Rhizomes thin, with adventitious roots, stolons absent. Stem solitary, erect, unbranched except for inflorescence, glabrous or puberulent in upper part. Leaves slightly leathery, narrowly lanceolate, apex acute, base gradually narrowing, subclasping, abaxially light green, adaxially dark green and glossy, 3-veined, midvein abaxially prominent; rosulate leaves 4–13 × 0.4–1.7 cm, margin serrate, petiole 3–11 cm long, both surfaces glabrous; lower cauline leaves persistent at anthesis or rarely withered, 3–10 × 0.3–0.8 cm, sessile or with obscure petioles, margin entire or serrate, abaxially glabrous, adaxially sparsely strigose; middle cauline leaves sessile or with obscure petiole, 4–7 × 0.3–0.4 cm, margin entire or serrate, abaxially glabrous, adaxially sparsely strigose; upper leaves sessile, margin entire. Capitula 9–20 (40) in a terminal corymbose cyme, peduncle puberulent. Involucre campanulate, 5–8 mm in diameter; phyllaries in 5–7 rows, imbricate, lanceolate,

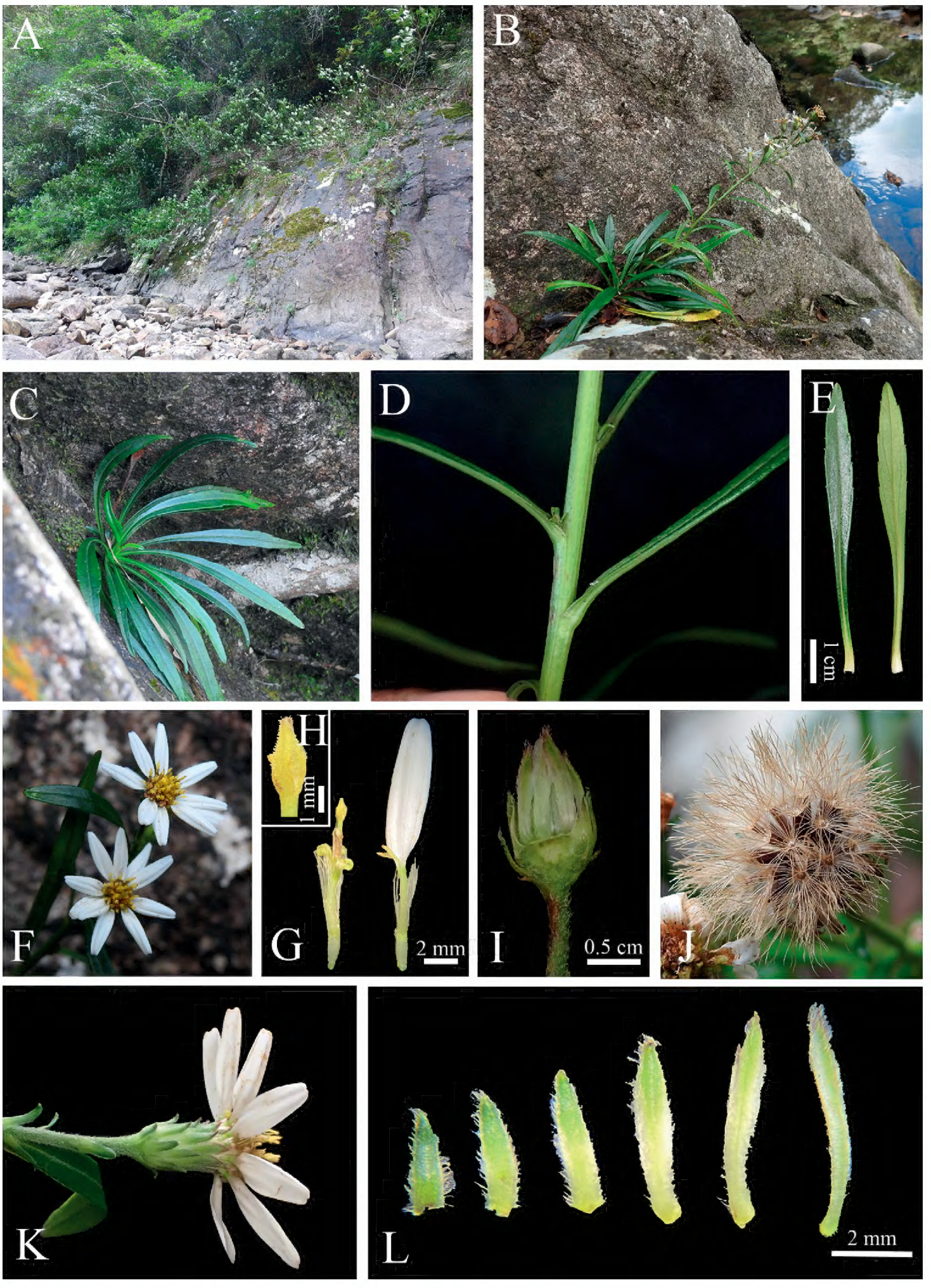

Figure 2. Images of living plants of *Aster quanzhouensis* **A** habitat **B** habit **C** seedling **D** steam **E** rosulate leaves **F** top view of the capitulum **G** a disk floret (left) and a ray floret (right) **H** style branches of a disk floret **I** receptacle **J** fruits **K** dorsal view of a capitulum **L** phyllaries (from outer to inner, left to right).

Figure 3. Holotype of *Aster quanzhouensis* M.Tang, G.J.Yan & W.P.Li.

the outer rows shorter than the inner ones, reflexed, densely pilose, with ciliate margin; outer phyllaries 3.2–6.2 × 1.1–2 mm; middle phyllaries 4.6–13 × 1.5–2.2 mm, with narrowly scarious margin, tip purplish-red; inner phyllaries 10.1–13.0 ×1.5–1.7 mm, with broadly scarious margin, tip purplish-red. Receptacles flat, alveolate. Ray florets 7–11, female, tube ca. 4 mm, glabrous, ligules whitish, lanceolate, 11–14 × ca. 2 mm, with four nerves, apex with two or three teeth. Disc florets (11) 18–24, hermaphrodite, yellow, tube puberulent, ca. 3 mm, thin but expanded at base, 5-lobed, lobes spreading to reflexed, narrowly triangular, unequal, 1.1–1.5 mm, glandular; anthers ca. 1.8 mm (excluding collar), apical appendage 0.35–0.45 mm long, narrowly lanceolate, anther collar ca. 0.4 mm long; style arm appendage lanceolate, ca. 2.5 mm, stigmatic lines 1.2–1.4 mm, equal to the sterile style tip appendages. Achenes 4.5–5.5 × 0.9–1.4 mm, narrowly oblong, strigose, eglandular, two- or three-ribbed. Pappus uniseriate, dirty white, 8–11 mm, nearly as long as disc corolla at anthesis.

Phenology. Flowering from September to early December and fruiting from October to December.

Etymology. The species is named after its type locality, Quanzhou city, Fujian province, China.

Vernacular name. quán zhōu zǐ wǎn (Chinese pronunciation); 泉州紫菀 (Chinese name).

Distribution and habitat. *Aster quanzhouensis* is known from Dehua and Yongchun counties, Quanzhou city, Fujian province, China. The new species grows on rocks in riparian habitats at an altitude of ca. 500 m a.s.l.

Conservation status. *Aster quanzhouensis* seems to be a narrowly distributed species, currently known only in rocky areas along two streams (Jin river and Min river) in Quanzhou city, and each population with ca. 150 (total < 1000) individuals were found. The habitat of *A. quanzhouensis* is easily disturbed or damaged. Further fieldwork is needed to evaluate the exact distribution of the species, and it is possible that other populations could be found in similar habitats of the Jin and Min rivers. Therefore, we only temporarily assign the species to the category DD (Data Deficient) according to the International Union for Conservation of Nature (IUCN 2022).

Table 1. Comparison of *Aster quanzhouensis* and *A. tonglingensis*. The data of the latter species were taken from Zhang et al. (2019).

Characters	*Aster quanzhouensis*	*A. tonglingensis*
Stem	21–30(60) cm, solitary	70–100 cm, solitary or two to three
Basal leaves	narrowly lanceolate, 4–13 × 0.4–1.7 cm	lanceolate, 4–18 × 0.8–2.5 cm
Capitula	9–20 (40)	More than 30
Phyllaries	5–7-seriate, apex purplish-red	5–7-seriate, apex green
Ray florets	7–11	ca. 15
Achenes	2–3-ribbed	4-ribbed
Pappus	8–11 mm	ca. 7 mm
Flowering period	Sep to early Dec	Jul

Cytology

The somatic chromosomes of the new species at metaphase are illustrated in Fig. 4. The two populations have a same karyotype formula, 2n = 18, and Stebbins' 1A-type (Stebbins 1971), but differs in ratio of long to short arm of chromosomes (the former is 1.02–1.55, while the latter 1.06–1.45), the chromosomes length (the former is 1.49–2.72, while the latter 1.71–2.77), and the AI value (the former is 0.54, while the latter 0.57).

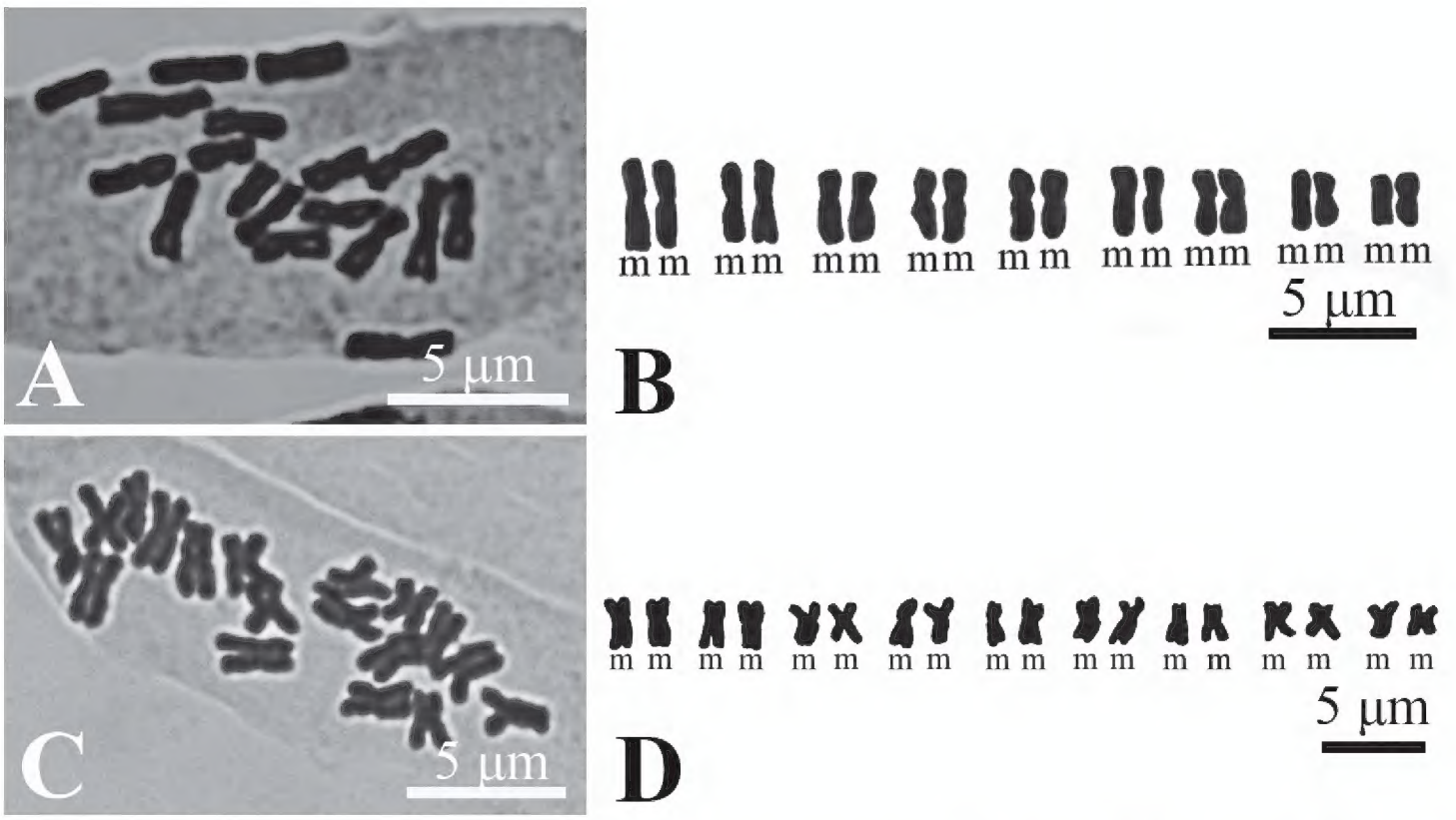

Figure 4. Micrographs of somatic metaphase chromosomes (**A, C**) and the karyotype (**B, D**) of *Aster quanzhouensis* from two different populations. (**A, B** Dehua county, Quanzhou, Fujian, China; **C, D** Yongchun county, Quanzhou, Fujian, China).

Molecular phylogeny

The aligned lengths of ITS, ETS and *trnL-F* are 647 bp, 568 bp and 957 bp, respectively, yielding a concatenated alignment of 2172 bp. Character state changes were equally weighted and gaps were treated as missing data. ML and BI analyses produced similar topology and only the ML tree was presented in Fig. 5, with ML bootstrap (LP), and PP values for each clade. The phylogenetic results showed that the two samples of the new taxon were grouped together with strong support (PP = 1.00, LP = 100%) and are closely related to *Aster tonglingensis* with strong support (PP = 1.00, LP = 99%). According to these results, *A. quanzhouensis* is nested within the core *Aster* clade (PP = 1.00, LP = 100%) that is the redefined genus *Aster* in Eurasia (Li et al. 2012; Nesom 2020a, b).

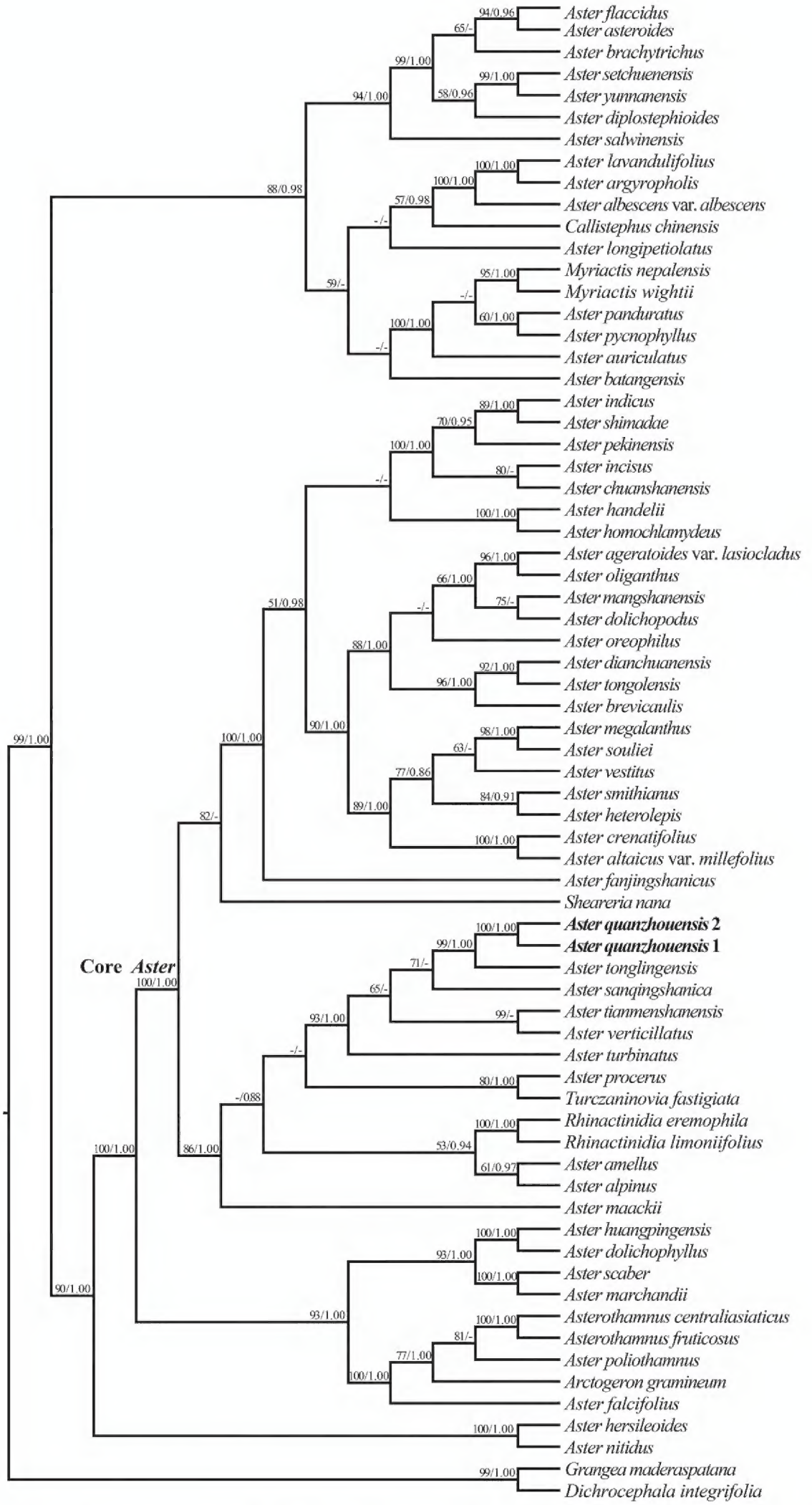

Figure 5. The phylogram of the maximum likelihood (ML) tree from the combined data (ITS, ETS and *trnL-F*), showing the phylogenetic position of *Aster quanzhouensis*. Bootstrap support values (1,000 replicates) for maximum parsimony (MP ≥ 50%, left) and Bayesian posterior probabilities (PP ≥ 0.90, right) are provided above the branches. The samples of *Aster quanzhouensis* are shown in bold.

Discussion

Morphological observations showed that *Aster quanzhouensis* has a perennial life form, lanceolate stigmatic appendage of disc florets, compressed fruits with two- or three-ribbed and uniseriate pappus (Figs 2, 3). All *Aster* species share these characters. In the phylogenetic tree (Fig. 5), *A. quanzhouensis* is deeply nested within the core *Aster* (Li et al. 2012). Morphological and phylogenetic analyses support that *A. quanzhouensis* is sister to *A. tonglingensis*. As mentioned above, the two species can be easily distinguished from each other (Figs 2, 3, Table 1).

Narrowly lanceolate leaves are rare in Eurasian *Aster* and can be found only in a few species, such as *A. huangpingensis* W.P.Li & Z.Li, *A. dolichophyllus* Y.Ling and *A. tonglingensis*. Our phylogenetic analyses (Fig. 5) revealed that the species with narrowly lanceolate leaves are nested in unrelated lineages of the genus *Aster* and are probably the result of convergent evolution. It is noteworthy to mention that they are all distributed in the same habitats confined to riparian rocks (Chen et al. 2011; Zhang et al. 2019; Li et al. 2020). The same leaf character may be related to their habitat. When the water level rises in some periods during the course of the year, these species were submerged and their narrowly lanceolate leaves may represent adaptation to water flowing in the rivers or streams.

Karyotype variation usually accompanies evolutionary divergence, a general phenomenon observed in plants and animals (Rieseberg 2001). Two populations of the *Aster quanzhouensis* were found with the same karyotype formula and Stebbins' type, with only slight differences in the karyotypic indexes, which might mean that *A. quanzhouensis* is a young species.

Aster quanzhouensis is known only from two populations (Dehua and Yongchun counties) restricted to Quanzhou, Fujian, China, while *A. tonglingensis* is restricted to Mt. Tongling Natural Reserve, Wencheng county, Zhejiang (Zhang et al. 2019). These two species occupy the same ecological conditions, but are geographically separated by a distance of 400 km.

Acknowledgements

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Appendix 1

Table A1. Taxa sampled, vouchers and GenBank accessions. The newly sequenced samples are highlighted in bold.

Accessions	Voucher information or references	Accession number		
		ITS	ETS	*trnL-F*
***Aster quanzhouensis* M.Tang, G.J.Yan & W.P.Li 1**	*Guo-Jiao Yan*, *YGJ2110001*, Dehua county, Fujian, China	ON055150	ON055152	ON055154
***Aster quanzhouensis* M.Tang, G.J.Yan & W.P.Li 2**	*Guo-Jiao Yan*, *YGJ2112001*, Yongchun county, Fujian, China	ON055151	ON055153	ON055155
A. sanqingshanica J.W.Xiao & W.P.Li	Xiao et al. (2021)	MW419955	MW419952	ON055156
A. marchandii H.Lév.	Xiao et al. (2021)	MW419957	MW419954	ON055157

Accessions	Voucher information or references	Accession number		
		ITS	ETS	*trnL-F*
A. dianchuanensis J.W.Xiao & W.P.Li	Xiao et al. (2019b)	MK693180	MK693190	MK693202
A. brevicaulis W.P.Li	Xiao et al. (2019a)	MH638204	MH638209	MH638218
A. tongolensis Franch.	Xiao et al. (2019b)	MK693183	MK693193	JN543834
A. ageratoides var. *lasiocladus* (Hayata) Hand.-Mazz.	Li et al. (2012)	JN543781	JN543782	JN543783
A. oliganthus W.P.Li & Z.Li	Li et al. (2017)	KY428860	KY428852	MH638219
A. mangshanensis Y.Ling	Li et al. (2012)	JN543760	JN543761	JN543762
A. oreophilus Franch.	Li et al. (2012)	JN543826	JN543827	JN543828
A. dolichopodus Y.Ling	Li et al. (2012)	JN543775	JN543776	JN543777
A. vestitus Franch.	Li et al. (2012)	JN543769	JN543770	JN543771
A. souliei Franch.	Li et al. (2012)	JN543835	JN543836	JN543837
A. megalanthus Y.Ling	Xiao et al. (2019b)	MK693187	MK693197	MK693207
A. smithianus Hand.-Mazz.	Li et al. (2012)	JN543778	JN543779	JN543780
A. heterolepis Hand.-Mazz.	Li et al. (2012)	JN543823	JN543824	JN543825
A. altaicus var. *millefolius* (Vaniot) Hand.-Mazz.	Li et al. (2012)	JN543709	JN543710	JN543711
A. crenatifolius Hand.-Mazz.	Li et al. (2012)	JN543712	JN543713	JN543714
A. fanjingshanicus Y.L.Chen & D.J.Liu	Li et al. (2012)	JN543829	JN543830	JN543831
A. pekinensis (Hance) F.H.Chen	Li et al. (2012)	JN543718	JN543719	JN543720
A. shimadae (Kitamura) Nemoto	Xiao et al. (2020)	MT731682	MT731599	ON055158
A. indicus L.	Li et al. (2012)	JN543715	JN543716	JN543717
A. incisus Fisch.	Li et al. (2012)	JN543721	JN543722	JN543723
A. chuanshanensis W.P.Li	Xiao et al. (2020)	MT731676	MT731593	ON055159
A. homochlamydeus Hand.-Mazz.	Li et al. (2012)	JN543784	JN543785	JN543786
A. handelii Onno	Li et al. (2012)	JN543820	JN543821	JN543822
A. maackii Regel	Li et al. (2012)	JN543745	JN543746	JN543747
A. turbinatus S.Moore	Li et al. (2012)	JN543814	JN543815	JN543816
A. verticillatus (Reinw.) Brouillet	Li et al. (2012)	JN543706	JN543707	JN543708
A. tianmenshanensis G.J.Zhang & T.G.Gao	Zhang et al. (2015)	KP313677	KP313690	KP313703
A. tonglingensis G.J.Zhang & T.G.Gao	Zhang et al. (2019)	MH807119	MH807124	MH807126
A. procerus Hemsl.	Zhang et al. (2015)	KP313683	KP313696	KP313709
A. amellus Grierson	Li et al. (2012)	JN543742	JN543743	JN543744
A. alpinus L.	Li et al. (2012)	JN543817	JN543818	JN543819
A. falcifolius Hand.-Mazz.	Li et al. (2012)	JN543802	JN543803	JN543804
A. poliothamnus Diels	Li et al. (2012)	JN543763	JN543764	JN543765
A. scaber Thunb.	Li et al. (2012)	JN315934	JN315958	JN315910
A. huangpingensis W.P.Li & Z.Li	Li et al. (2020)	MH747070	MH747071	ON055160
A. dolichophyllus Y.Ling	Zhang et al. (2019); Li et al. (2020)	MH747068	MH747069	MH807108
A. hersileoides C.K.Schneid.	Li et al. (2012)	JN543787	JN543788	JN543789
A. nitidus C.C.Chang	Li et al. (2012)	JN543790	JN543791	JN543792
A. salwinensis Onno	Zhang et al. (2015)	KP313689	KP313702	KP313715
A. diplostephioides (DC.) Benth. ex C.B.Clarke	Li et al. (2012)	JN543847	JN543848	JN543849
A. setchuenensis Franch.	Li et al. (2012)	JN543850	JN543851	JN543852
A. yunnanensis Franch.	Li et al. (2012)	JN543853	JN543854	JN543855
A. brachytrichus Franch.	Li et al. (2012)	JN543838	JN543839	JN543840
A. asteroides (DC.) Kuntze	Li et al. (2012)	JN543841	JN543842	JN543843
A. flaccidus Bunge	Li et al. (2012)	JN543844	JN543845	JN543846
A. batangensis Bureau & Franch.	Li et al. (2012)	JN543859	JN543860	JN543861

Accessions	Voucher information or references	Accession number		
		ITS	ETS	*trnL-F*
A. panduratus Nees ex Walp.	Li et al. (2012)	JN543757	JN543758	JN543759
A. auriculatus Franch.	Li et al. (2012)	JN543754	JN543755	JN543756
A. pycnophyllus Franchet ex W.W.Sm.	Li et al. (2012)	JN543799	JN543800	JN543801
A. longipetiolatus C.C.Chang	Li et al. (2012)	JN315936	JN315960	JN315912
A. lavandulifolius Hand.-Mazz.	Li et al. (2012)	JN543796	JN543797	JN543798
A. argyropholis Hand.-Mazz.	Li et al. (2012)	JN543793	JN543794	JN543795
A. albescens (DC.) Wall. ex Hand.-Mazz. var. *albescens*	Li et al. (2012)	JN543862	JN543863	JN543864
Sheareria nana S.Moore	Li et al. (2012)	JN543703	JN543704	JN543705
Arctogeron gramineum (L.) DC.	Li et al. (2012)	JN315928	JN315952	JN315904
Asterothamnus fruticosus (C.Winkl.) Novopokr.	Li et al. (2012)	JN315929	JN315953	JN315905
A. centraliasiaticus Novopokr.	Li et al. (2012)	JN315930	JN315954	JN315906
Callistephus chinensis (L.) Nees	Li et al. (2012)	JN315931	JN315955	JN315907
Myriactis wightii DC.	Li et al. (2012)	JN315922	JN315946	JN315898
M. nepalensis Less.	Li et al. (2012)	JN315921	JN315945	JN315897
Rhinactinidia limoniifolia (Less.) Novopokr. ex Botsch.	Li et al. (2012)	JN543724	JN543725	JN543726
Rh. eremophila (Bunge) Novopokr. ex Botsch.	Li et al. (2012)	JN543727	JN543728	JN543729
Turczaninovia fastigiata (Fisch.) DC	Li et al. (2012)	JN543739	JN543740	JN543741
Grangea maderaspatana (L.f.) Kuntze	Li et al. (2012)	JN315920	JN315944	JN315896
Dichrocephala integrifolia (L.) Poir.	Li et al. (2012)	JN315919	JN315943	JN315895